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states that:

(1) I am fully conversant both with the Japanese and English languages.

(2)(A) I have translated into English Japanese Patent Application Number 2000-337433, filed November 6, 2000. A copy of said English translation is attached hereto.

(2)(B) I have carefully compared the attached English-language translation of Japanese Patent Application Number ______, filed ______ with the original Japanese-language patent application.

(3) The translation is, to the best of my knowledge and belief, an accurate translation from the original into the English language.

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[Title of the Invention] METHOD OF MANUFACTURING GLASS SUBSTRATE FOR INFORMATION RECORDING MEDIA, GLASS SUBSTRATE FOR INFORMATION RECORDING MEDIA MANUFACTURED USING THE METHOD, AND INFORMATION RECORDING MEDIUM USING THE GLASS SUBSTRATE

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[Name of Document] SPECIFICATION

[Title of the Invention] METHOD OF MANUFACTURING GLASS SUBSTRATE FOR INFORMATION RECORDING MEDIA, GLASS SUBSTRATE FOR INFORMATION RECORDING MEDIA MANUFACTURED USING THE METHOD, AND INFORMATION RECORDING MEDIUM USING THE GLASS SUBSTRATE

[What is claimed is]

[Claim 1]

A method of manufacturing a glass substrate for information recording media, including a smoothing step for smoothing at least one of an outer peripheral edge surface and an inner peripheral edge surface of a donut-shaped glass disk for information recording media by melt-heating to a temperature at or above a softening point of the glass by irradiating with a laser beam.

[Claim 2]

A method as claimed in claim 1, further comprising the step of processing said glass disk from a mother glass into a circular shape before carrying out said smoothing step.

[Claim 3]

A method as claimed in claim 2, further comprising the step of grinding using a grindstone the outer peripheral edge surface of the glass disk that has been processed into a circular shape.

[Claim 4]

A method as claimed in claim 3, further comprising the step of chamfering the outer peripheral edge surface into a predetermined shape after said grinding step.

[Claim 5]

A method as claimed in any one of claims 1 to 4, wherein both the outer peripheral edge surface and the inner peripheral edge surface are melt-heated in said

smoothing step.

[Claim 6]

A method of manufacturing a glass substrate for information recording media as claimed in claim 5, wherein said smoothing step comprises emitting a laser beam from a single laser oscillator, and alternately irradiating the emitted laser beam onto the inner peripheral edge surface and the outer peripheral edge surface.

[Claim 7]

A method as claimed in claim 6, wherein the smoothing step comprises emitting a laser beam from a single laser oscillator, splitting the laser beam into two split laser beams, and simultaneously irradiating the two split laser beams onto the inner peripheral edge surface and the outer peripheral edge surface respectively.

[Claim 8]

A method as claimed in claim 5, wherein said smoothing step comprises emitting said laser beam from each of two laser oscillators, and irradiating the laser beam emitted from one of said laser oscillators onto said inner peripheral edge surface, and irradiating the laser beam emitted from said other laser oscillator onto said outer peripheral edge surface.

[Claim 9]

A method as claimed in any one of claims 1 to 8, wherein said at least one laser beam is a divergent beam.

[Claim 10]

A method as claimed in any one of claims 1 to 9, wherein said glass disk is rotated during said smoothing step such that a speed of said inner peripheral edge surface relative to said laser beam is in a range of 0.02 to 5.0 m/minute.

[Claim 11]

A method as claimed in claim 10, wherein a ratio of an energy density of said laser beam on said outer peripheral edge surface to an energy density of said laser beam on said inner peripheral edge surface is more than 1.

[Claim 12]

A method as claimed in claim 11, wherein the ratio of the energy density of said laser beam on said outer peripheral edge surface to the energy density of said laser beam on said inner peripheral edge surface is in a range of 2 to 5.

[Claim 13]

A method as claimed in any one of claims 1 to 12, wherein all or part of said glass disk is heated using a resistive heater before or during said smoothing step.

[Claim 14]

A method as claimed in any one of claims 1 to 13, further comprising grinding and polishing a major surface of said glass disk after said smoothing step.

[Claim 15]

A method as claimed in claim 14, wherein a mother glass of said glass disk is a silicate glass containing at least Li_2O or Na_2O as an alkaline oxide component, and the method further comprises the step of carrying out chemical strengthening treatment wherein an alkaline component in a surface layer of the glass disk is replaced with an alkaline component having a larger ionic radius, after the smoothing step has been carried out on the major surface of the glass disk.

[Claim 16]

A glass substrate for information recording media prepared using the method as claimed in any one of claims 1 to 15.

[Claim 17]

A glass substrate for information recording media as

claimed in claim 16, wherein an average roughness Ra of at least one of the inner peripheral edge surface and the outer peripheral edge surface is in a range of 0.001 to 0.3μm.

[Claim 18]

A glass substrate for information recording media as claimed in claim 16 or 17, wherein a maximum roughness Rmax of at least one of the inner peripheral edge surface and the outer peripheral edge surface is in a range of 0.01 to 2μm.

[Claim 19]

An information recording medium comprising a glass substrate for information recording media as claimed in any one of claims 16 to 18 with an information recording film formed on said major surface thereof.

[Claim 20]

An information recording medium as claimed in claim 19, wherein the information recording film is a magnetic recording film.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a method of manufacturing a glass substrate for information recording media, a glass substrate for information recording media manufactured using the method, and an information recording medium using the glass substrate.

[0002]

[Prior Art]

Information recording media include magnetic disks, optical magnetic disks and optical disks. A magnetic disk, for example, generally has a donut shape with a hole in the center thereof, and a magnetic film that acts as a data recording medium is covered onto one or both major surfaces of the disk. Data is recorded onto such a

magnetic disk by means of differences in strength of magnetism.

[0003]

A glass substrate for such a magnetic disk is usually manufactured through a manufacturing process described below.

[0004]

FIG. 9 is a flow chart of a conventional manufacturing process for a glass substrate for a magnetic disk.

[0005]

First, a starting material glass plate of thickness 1.0mm is prepared (step P1). Next, a donut-shaped glass disk having an outside diameter of 84mm and an inside diameter of 25mm is cut out from the starting material glass plate (step P2). The method of doing this is to irradiate with a laser beam along cutting lines to cause strain or insert cutting lines using a wheel cutter, and then cut along the cutting lines. The cutting lines run along the outer periphery and the inner periphery of the glass disk; the outer cutting line is set 0.5 to 1.0mm outside the outer periphery, and the inner cutting line 0.5 to 1.0mm inside the inner periphery.

[0006]

The next step is to grind the cut-out surfaces at the outer and inner peripheries of the glass disk, thus adjusting the outside and inside diameters (step P3). After the grinding, the average roughness Ra is, for example, 0.3 to 0.4μm, and the maximum roughness Rmax, for example, 3 to 4μm. The grinding and chamfering is carried out using a diamond grindstone on one glass disk at a time, and is comprised of first stage grinding using a #324 roughness (coarse), and second stage grinding using a #500 roughness (fine). The chamfering is carried out at an angle of 45°, and 0.15mm is chamfered at a time.

[0007]

Next, 30 or so of the glass disks are stacked on top of one another, and the outer peripheral edge surfaces of the glass disks are polished using an outer peripheral edge surface polishing machine (step P4), and then 100 of the glass disks are stacked on top of one another, and the inner peripheral edge surfaces of the glass disks are polished using an inner peripheral edge surface polishing machine (step P5). Each of these two polishing steps is carried out by pushing a rotating brush against the surfaces to be polished of the rotating stacked glass disks while spraying a cerium oxide slurry on the surfaces. After the polishing, the average roughness Ra is, for example, 0.05 to 0.4μm, and the maximum roughness Rmax, for example, 0.3 to 2.5μm.

[0008]

The major surfaces of the glass disks are then polished by sandwiching the glass disks at the major surfaces between two pads impregnated with a cerium oxide slurry and rotating (step P6). Next, abrasive grains and the like attached to the glass disks are washed off using warm water, alkaline washing water or pure water (step P7), and then the glass disks are strengthened using chemical strengthening treatment (step P8). Finally, salt from the chemical strengthening treatment, foreign matter and the like attached to the glass disks are once again washed off using warm water, alkaline washing water or pure water (step P9).

[0009]

In general, the inside and outside peripheral edge surfaces of a magnetic disk are not used as data recording surfaces. Nevertheless, the inner and outer peripheral edge surfaces of the glass disk are ground and polished in steps P3 to P5 of the manufacturing process described above, because cracks and undulations

inevitably remain on the cut-out surfaces at the inside and outside peripheries of the glass disk after the glass disk is cut out in step P2, and such cracks may lead to fracture of the glass disk, and moreover foreign matter such as abrasive grains that appear during the manufacturing process may collect in the recessed parts of such undulations, and this foreign matter may fly out when the glass disk is used as a magnetic disk and rotated at high speed, adversely affecting the recording surfaces.

[0010]

[Problems to Be Solved by the Invention]

The conventional method of manufacturing a glass substrate for information recording media described above, however, suffers from the following problems:

(1) The grinding/chamfering step P3 and the polishing steps P4 and p5 are time-consuming and costly, and moreover variation in surface roughness between glass disks and variation in surface roughness from place to place on a single glass disk occur.

(2) Setting of glass disks must be carried out separately for the inner peripheral edge surface polishing machine and the outer peripheral edge surface polishing machine, and hence many operators are required, and the cost is high.

(3) To improve the processing efficiency, polishing is carried out simultaneously on 100 or so glass disks stacked on top of one another using the inner peripheral edge surface polishing machine, and 30 or so glass disks stacked on top of one another using the outer peripheral edge surface polishing machine, and hence the major surfaces of the glass disks rub against one another and may become scratched.

(4) Even after the grinding and chamfering steps and the polishing step in P3 to P5, fine cracks of depth, for

example, 1 to 60μm may remain, resulting in the strength of the glass dropping. Moreover, if there are cracks or the like on the inner and outer peripheral edge surfaces of the glass disk, then the strength will not increase sufficiently even if chemical strengthening treatment is carried out.

(5) Large-grained glass powder generated during the grinding in step P3 may adhere to the major surfaces of the glass disk, resulting in scratches.

(6) In step P5 in particular, uneven polishing may occur due to the rotating brush not contacting the stacked glass disks uniformly, resulting in the problem of the extent of polishing varying between the glass disks.

[0011]

It is an object of the present invention to provide a method of manufacturing a glass substrate for information recording media that allows the inner and outer peripheral edge surfaces of the glass substrate for information recording media to be smoothed easily and inexpensively, a glass substrate for information recording media manufactured using this method, and an information recording medium using this glass substrate.

[0012]

[Means for Solving the Problems]

To attain the above object, the method described in claim 1 is a method including a smoothing step for smoothing at least one of an outer peripheral edge surface and an inner peripheral edge surface of a donut-shaped glass disk for information recording media by melt-heating to a temperature at or above a softening point of the glass by irradiating with a laser beam.

[0013]

According to the method of manufacturing described in claim 1, at least one of the outer peripheral edge

surface and the inner peripheral edge surface of the glass disk becomes smooth and rounded, and hence a polishing step used in a conventional method can be omitted, and moreover chamfering in a grinding step can also be omitted.

[0014]

The method of manufacturing described in claim 2 is a method of manufacturing as described in claim 1, further comprising the step of processing the glass disk from a mother glass into a circular shape before carrying out the smoothing step.

[0015]

The method to process the glass substrate for an information recording media of the present invention from a mother glass into a circular shape is to draw a cutting line of a donut shape circle having a slightly larger outer periphery and a slightly smaller inner periphery than the desired glass disk. Then a circular processing method may be employed in which the glass substrate is cut along the cutting lines. Further, a circular processing method may be employed in which the melted glass is slushed into a mold and made into a circular shape, then is the inner periphery is processed into a donut shape. Still further, a circular processing method in which the melted glass may be processed directly into a donut shape having an outer and inner periphery may be employed.

[0016]

The method of manufacturing described in claim 3 is a method of manufacturing as described in claim 2, further comprising the step of grinding using a grindstone the outer peripheral edge surface of the glass disk that has been processed into a circular shape.

[0017]

The grinding step of the present invention is

carried out by attaching normally diamond abrasive grains having approximately #300 to #500 roughness to the edge of a rotating grindstone, and rotating and pushing the grindstone against the edge surfaces of the glass disk, until the inside diameter and the outside diameter becomes the predetermined values.

[0018]

The method of manufacturing described in claim 4 is a method of manufacturing as described in claim 3, further comprising the step of chamfering the outer peripheral edge surface into a predetermined shape after the grinding step.

[0019]

The chamfering step of the present invention is carried out by polishing using normally diamond abrasive grains having approximately #500 to #600 roughness. By carrying out this chamfering step, the degree of unevenness on the edge portions of the glass caused by grinding decreases. Therefore, it is possible to further prevent glass powder, foreign matters in the air, and residual abrasive grains from entering into recessed parts and remaining even after processes such as washing. The chamfering step is carried out on the inner peripheral edge surface, the outer peripheral edge surface or on both edge surfaces.

[0020]

The method of manufacturing described in claim 5 is a method of manufacturing as described any one of claims 1 to 4, wherein both the outer peripheral edge surface and the inner peripheral edge surface are melt-heated in said smoothing step.

[0021]

The laser beam irradiation of the present invention is carried out on; the cut surface of the glass formed when the glass is separated from the glass substrate, the

grinding surface of the glass is grind by using a diamond abrasive grain, and the chamfering surface chamfered to a predetermined shape after the grinding step. Especially with the grinding surface, when observed with a scanning microscope of about 1000 times, many microscopic recess can be found, and dust from the grinding, dust floating in the air, and glass powder from the grinding can easily fix to the recess portions. The, after the glass is subject to; grinding and polishing of the recording surface, chemical strengthening treatment using molten salt including potassium sulfate, and washing, it becomes difficult to remove the fixed foreign matters from the recess. However, since the smoothing process of the present invention is carried out by irradiating a laser beam to the side surfaces of the glass disk, all or part of the inner and outer peripheral surfaces of the glass disk is melt-heated to cause the glass to flow. As a result, it is possible to smooth the glass without foreign matters fixing or attaching to the glass.

[0022]

The method of manufacturing described in claim 6 is a method of manufacturing as described in claim 5, wherein the smoothing step comprises emitting a laser beam from a single laser oscillator, and alternately irradiating the emitted laser beam onto the inner peripheral edge surface and the outer peripheral edge surface.

[0023]

The method of manufacturing described in claim 7 is a method of manufacturing as described in claim 6, wherein the smoothing step comprises emitting a laser beam from a single laser oscillator, splitting the laser beam into two split laser beams, and simultaneously irradiating the two split laser beams onto the inner peripheral edge surface and the outer peripheral edge

surface respectively.

[0024]

The method of manufacturing described in claim 8 is a method of manufacturing as described in claim 5, wherein the smoothing step comprises emitting the laser beam from each of two laser oscillators, and irradiating the laser beam emitted from one of the laser oscillators onto the inner peripheral edge surface, and irradiating the laser beam emitted from the other laser oscillator onto the outer peripheral edge surface.

[0025]

The method of manufacturing described in claim 9 is a method of manufacturing as described in any one of claims 1 to 8, wherein the at least one laser beam is a divergent beam.

[0026]

According to the method of manufacturing described in claim 9, since the laser beam is a divergent beam, it can reliably prevent the beam from being irradiated onto the major surface of the glass disk and thus melting that surface.

[0027]

The method of manufacturing described in claim 10 is a method of manufacturing as described in any one of claims 1 to 9, wherein the glass disk is rotated during the smoothing step such that a speed of the inner peripheral edge surface relative to said laser beam is in a range of 0.02 to 5.0 m/minute.

[0028]

In the case that the smoothing step is completed after rotating the glass once (so called 'one-shot melting') , it is preferable to set the circumferential speed to 0.2 to 1.0 m/minute. If the glass is melted and smoothed by rotating the glass several times, it is preferable to set the circumferential speed to 0.4 to 5

m/minute.

[0029]

The method of manufacturing described in claim 11 is a method of manufacturing as described in claim 10, wherein a ratio of an energy density of the laser beam on the outer peripheral edge surface to an energy density of the laser beam on the inner peripheral edge surface is more than 1.

[0030]

The method of manufacturing described in claim 12 is a method of manufacturing as described in claim 11, wherein the ratio of the energy density of the laser beam on the outer peripheral edge surface to the energy density of the laser beam on said inner peripheral edge surface is in a range of 2 to 5.

[0031]

The method of manufacturing described in claim 13 is a method of manufacturing as described in any one of claims 1 to 12, wherein all or part of the glass disk is heated using a resistive heater before or during the smoothing step.

[0032]

The method of manufacturing described in claim 14 is a method of manufacturing as described in any one of claims 1 to 13, further comprising grinding and polishing a major surface of the glass disk after the smoothing step.

[0033]

The major surfaces of the glass substrates for information recording media are used for information recording surfaces and information reading, and thus the recording surfaces are finished to a smooth surface. Especially for glass substrates for magnetic recording media, the major surfaces of the glass disk is ground using a fixed diamond grindstone to adjust the thickness

to a predetermined thickness, and then are precision polished using a suspension containing cerium oxide to further smooth the surface. Even when treated to such processing using grindstones and microscopic powders for polishing, the edge surfaces of the glass disk of the present invention which has been treated to the smoothing step by heat-melting is substantially prevented from residuals and glass dust from grinding and polishing attaching and fixing to the edge surfaces.

[0034]

The method of manufacturing described in claim 15 is a method of manufacturing as described in claim 14, wherein a mother glass of the glass disk is a silicate glass containing at least Li_2O or Na_2O as an alkaline oxide component, and the method further comprises the step of carrying out chemical strengthening treatment wherein an alkaline component in a surface layer of the glass disk is replaced with an alkaline component having a larger ionic radius, after the smoothing step has been carried out on the major surface of the glass disk.

[0035]

According to the method of manufacturing described in claim 15, the mother glass of the glass disk is a silicate glass containing at least Li_2O or Na_2O as an alkaline oxide component, and the method further comprises the step of carrying out chemical strengthening treatment wherein an alkaline component in a surface layer of the glass disk is replaced with an alkaline component having a larger ionic radius, after the smoothing step has been carried out on the major surface of the glass disk. As a result, the strength of the glass disk can be increased.

[0036]

The glass substrate for information recording media described in claim 16 is prepared using the method as

claimed in any one of claims 1 to 15.

[0037]

The glass substrate for information recording media described in claim 17, is a glass substrate for information recording media as claimed in claim 16, wherein an average roughness Ra of at least one of the inner peripheral edge surface and the outer peripheral edge surface is in a range of 0.001 to 0.3μm.

[0038]

The glass substrate for information recording media described in claim 18, is a glass substrate for information recording media as claimed in claims 16 or 17, wherein a maximum roughness Rmax of at least one of the inner peripheral edge surface and the outer peripheral edge surface is in a range of 0.01 to 2μm.

[0039]

The glass substrate for information recording media described in claim 19, is a glass substrate for information recording media as claimed in any one of claims 16 to 18, with an information recording film formed on said major surface thereof.

[0040]

According to the present invention, an information recording medium can be obtained by forming an information recording film such as a magnetic recording film, an optical magnetic recording film or an optical recording film on one or both major surfaces of the glass substrate for information recording media according to the present invention as described above.

[0041]

The glass substrate for information recording media described in claim 20, is a glass substrate for information recording media as claimed in claim 19, wherein the information recording film is a magnetic recording film.

[0042]

Especially with a magnetic recording media, since the magnetic reading head travels at a very close distance from the recording surface during usage, any microscopic foreign matters on the recording surface will be a cause of a magnetic head crash. Therefore, a glass substrate free from attached matters is strongly requested.

[0043]

The magnetic recording media of the present invention can be illustrated by a glass substrate for information recording media of the present invention, in which the major surfaces thereof is covered with a bedding film containing chromium or chromium alloy, and a laminating layer including a alloy recording film, a protection film and a lubrication film. Especially the magnetic recording film is used preferably in a magnetic film of metallic magnetic films containing platinum, for reading and writing with a magneto-resistive head (MR head) or a large magneto-resistive head (GMR head).

[0044]

[Embodiments]

Embodiments of the method of manufacturing a glass substrate for information recording media according to the present invention will now be described with reference to the drawings.

[0045]

FIG. 1 is a flow chart of a manufacturing process for a glass substrate for information recording media according to an embodiment of the present invention.

[0046]

First, a starting material glass plate of thickness 1.0mm is prepared (step P11). The mother glass of this starting material glass plate is preferably a silicate glass that is rigid and resistant to chemicals such as

alkalis, a crystallized glass made by crystallizing a silicate glass through heat treatment, or the like.

[0047]

Examples of the silicate glass include soda lime silicate glass which is used as window glass in building, aluminosilicate glass, borosilicate glass, and glass that can be easily chemically strengthened. The glass that can be easily chemically strengthened is a glass which is chemically strengthened by bringing the glass into contact with molten potassium nitrate to replace lithium ions and/or sodium ions in the glass with potassium ions, which have a larger ionic radius than lithium ions and sodium ions, or by bringing the glass into contact with molten sodium nitrate to replace lithium ions in the glass with sodium ions, which have a larger ionic radius than lithium ions, thus producing compressive stress in a surface layer (depth about 50 to 200μm) of the glass. An example of this type of glass contains as principal components 60 to 65mass% of SiO_2, 10 to 20mass% of Al_2O_3, 0 to 5mass% of MgO, 0 to 5mass% of CaO, 2 to 10mass% of Li_2O, and 5 to 15mass% of Na_2O. Moreover, a crystallized glass has principal components selected from SiO_2, Al_2O_3, Li_2O, MgO, P_2O_3, ZrO, CeO_2, TiO_2, Na_2O and K_2O.

[0048]

There are no particular limitations on the component of the crystallized glass, but a crystallized glass containing, for example, 70 to 80mass% of SiO_2, 2 to 8mass% of Al_2O_3, 1 to 7mass% of K_2O, 5 to 15mass% of Li_2O and 1 to 5mass% of P_2O_5 is preferable, as such a glass does not suffer heat fracture when irradiated with a laser beam, and hence edge surfaces thereof can be smoothed.

[0049]

The starting material glass plate is formed using a float glass manufacturing method, a down-draw

manufacturing method, or the like.

[0050]

A donut-shaped glass disk having an outside diameter of 84mm and an inside diameter of 25mm is cut out from the starting material glass plate (step P12). The method of doing this is to irradiate with a laser beam along the cutting lines to cause strain or insert the cutting lines using a wheel cutter, and then cut along the cutting lines. The cutting lines run along the outer periphery and the inner periphery of the glass disk; the outer cutting line is set 0.5 to 1.0mm outside the outer periphery, and the inner cutting line 0.5 to 1.0mm inside the inner periphery.

[0051]

The next step is to grind the cut-out surfaces at the outer and inner peripheries of the glass disk, thus adjusting the outside and inside diameters (step P13). After the grinding, the average roughness Ra is, for example, 0.3 to 0.4μm, and the maximum roughness Rmax, for example, 3 to 4μm. The grinding is carried out using a diamond grindstone on one glass disk at a time, and is comprised of first stage grinding using a #324 roughness (coarse), and second stage grinding using a #500 roughness (fine).

[0052]

Next, edge surface smoothing is carried out by irradiating a laser beam onto each of the inner peripheral edge surface and the outer peripheral edge surface of the glass disk using a laser beam irradiation apparatus, described below, thus heating the inner peripheral edge surface and the outer peripheral edge surface of the glass disk to a temperature at or above the softening point of the glass, for example 750°C or more, preferably about 1000°C, and hence melting and smoothing the inner and outer peripheral edge surfaces

(step P14). As a result, compressed layers can be formed on the inner and outer peripheral edge surfaces without scratches or fine cracks appearing. The mechanical strength of the glass disk can thus be increased.

[0053]

The major surfaces (information recording surfaces) of the glass disk that will be covered with information recording films are then ground using diamond grindstones and precision polished using a cerium oxide suspension, thus making the thickness of the glass disk a predetermined value and smoothing the surfaces (step P15). Washing is then carried out to remove abrasive grains used in the polishing and the like (step P16).

[0054]

Next, the glass disk is further strengthened using chemical strengthening treatment, so that the strength will be sufficient when the glass disk is rotated at high speed during use as an information recording medium (step P17). In the chemical strengthening treatment, to strengthen the glass disk, an alkaline component in a surface layer of the glass disk is replaced with an alkaline component having a larger ionic radius. Specifically, in the case of the glass disk using potassium nitrate (KNO_3) and sodium nitrate ($NaNO_3$) at 400 to 450°C, by immersing the glass disk in the molten salt for 2 to 5 hours, the sodium ions and lithium ions in the surface layer of the glass disk are replace with potassium ions and sodium ions, respectively, to thereby strengthen the glass disk.

[0055]

Finally, the glass disk that has been subjected to the chemical strengthening treatment is washed using warm water, alkaline washing water or pure water, to wash salt and other foreign matter of the like attached to the glass disk (step P18).

[0056]

FIG. 2 is a partially sectional view of an example of the laser beam irradiation apparatus used in step P14 shown in FIG. 1.

[0057]

In FIG. 2, a disk-shaped horizontal worktable 11 is connected to a perpendicular shaft 12, and is rotated about the vertical shaft 12 by a motor, not shown. A glass disk 14 for making a magnetic disk is placed on an upper surface of the worktable 11 via two annular seats 13, and thus rotates with the worktable 11. The glass disk 14 has been cut out from a starting material glass plate and inner and outer peripheral edge surfaces 15 and 16 thereof have been ground in steps P11 to P13 described above.

[0058]

An annular groove 17 is formed in the upper surface of the worktable 11 in concentricity with the worktable 11. A thermal insulating material 18 is fitted in the groove 17 and disposed along side walls and a bottom wall thereof, and an electrical heater 19 is inserted into the groove 17 for preheating the glass disk 14.

[0059]

The laser beam irradiation apparatus has a single laser oscillator 20. The laser oscillator 20 emits a laser beam in a horizontal direction, and the emitted laser beam is made into a parallel laser beam 22 by a collimator 21. The laser beam 22 is then alternately switched between a horizontal laser beam 24 and a lower end vertical laser beam 25 by means of a galvano-scan mirror 23. The laser beam 24 is irradiated via two stationary mirrors 26 and 27 onto the inner peripheral edge surface 15 of the glass disk 14, and the laser beam 25 is irradiated via one stationary mirror 28 onto the outer peripheral edge surface 16 of the glass disk 14.

[0060]

In the laser beam irradiation apparatus of FIG. 2, the speed of rotation of the worktable 1 is set such that the circumferential speed at the inner peripheral edge surface 19 of the glass disk 14 is 0.02 to 5.0 mm/minute.

[0061]

The laser oscillator 20 may be, for example, a YAG laser or a carbon dioxide laser, but a carbon dioxide laser is particularly preferable from the standpoint of the absorption coefficient.

[0062]

The dominant wavelength of the laser beam 20 is preferably 250 to 20,000nm, more preferably 900 to 12,000nm.

[0063]

If the energy densities of the laser beams 24 and 25 emitted from the laser oscillator 20 are too low, then the temperature of the glass will not be raised sufficiently, but it is pointless to make these energy densities too high since this will not result in any further increase in the temperature of the glass surfaces. Therefore, the energy densities are thus preferably in a range of 1 to $20W/mm^2$, more preferably 1 to $10W/mm^2$.

[0064]

The powers of the laser beams 24 and 25 are thus preferably in a range of 0.7 to 100W. Moreover, the ratio of the energy density of the laser beam 25 to the energy density of the laser beam 24 is preferably more than 1, and more preferably equal to the ratio of the outside diameter of the glass disk to the inside diameter thereof. As a result, the laser beam irradiation dose per unit length of the inner/outer peripheral edge surface of the glass disk will be the same for the inner and outer peripheral edge surfaces. Specifically, Table 1 shows the ratio of the outside diameter to the inside

diameter for various nominal magnetic disk sizes, and it can be seen from Table 1 that this ratio is in a range of 2.8 to 4.0; the above energy density ratio is thus preferably in a range of 2 to 5.

[0065]

[Table 1]

Nominal size of glass substrate for recording media	1"	1.8"	1.8"	2.5"	3"	3.5"
Outside diameter (mm ϕ)	27	48	48	65	84	95
Inside diameter (mm ϕ)	7	12	17	20	25	25
Ratio (Outside diameter /Inside diameter)	3.9	4.0	2.8	3.3	3.4	3.8

[0066]

An energy density ratio as described above can be realized by adjusting the time for which the galvano-scan mirror 23 is stopped in each position.

[0067]

In the laser beam irradiation apparatus constructed as above, the laser beam 22 may be alternately switched between the laser beam 24 and the laser beam 25 using a semicircular plate-shaped mirror (chopper) 31 rotated by a motor 30 as shown in FIG. 3 instead of the galvano-scan mirror 23. Another alternative may be to split the laser beam 22 into two laser beams 24 and 25 using a stationary half mirror, not shown in the drawings, whereby the laser beam 24 can be irradiated onto the inner peripheral edge surface 15 of the glass disk 14 and the laser beam 25 onto the outer peripheral edge surface 16 of the glass disk 14 simultaneously. In this case, the ratio of the power of the laser beam 25 to the power of the laser beam 24 can be changed by changing the reflectance of the half mirror.

[0068]

Moreover, the mirrors 27 and 28 are preferably convex as shown in FIG. 4. As a result, the laser beams 24 and 25 irradiated onto the inner and outer peripheral edge surfaces 15 and 16 respectively of the glass disk 14 can each be made into a divergent beam 29, and hence the laser beams 24 and 25 can be reliably prevented from being irradiated onto and thus melting the major surfaces of the glass disk 14. The angle of opening of the divergent beam is preferably 1 to 3 degrees. It goes without saying that the laser beams 24 and 25 may also be made divergent by not completely parallelizing the laser beam using the collimator 21, instead of using convex mirrors 27 and 28.

[0069]

FIG. 5 is a partially sectional view of a modified example of the laser beam irradiation apparatus used in step P14 shown in FIG. 1.

[0070]

In FIG. 5, a donut-shaped horizontal worktable 41 is connected to a prependicular shaft 43 via a cap-shaped connecting portion 42, and is rotated about the vertical shaft by a motor, not shown. A glass disk 46 for making a magnetic disk is placed on an upper surface of the worktable 41 via two annular seats 44, and thus rotates with the worktable 41.

[0071]

The glass disk 46 has been manufactured in the same way as the glass disk 14 shown in FIG. 2, and has an inner peripheral edge surface 47 and an outer peripheral edge surface 48. Moreover, a heater is provided along with a thermal insulating material in a groove in the upper surface of the worktable 41 as in the case of the worktable 11 shown in FIG. 2, but these items have been omitted from FIG. 5.

[0072]

The laser beam irradiation apparatus has a laser oscillator 50 for the outer peripheral edge surface 48 of the glass disk 46 and a laser oscillator 51 for the inner peripheral edge surface 47 of the glass disk 46. The laser beam emitted from the laser oscillator 50 is made into a parallel laser beam 53 by a collimator 52, and the laser beam 53 is then irradiated onto the outer peripheral edge surface 48 of the glass disk 46 via a mirror 54. The laser beam emitted from the laser oscillator 51, on the other hand, is made into a parallel laser beam 56 by a collimator 55, and then the laser beam 56 is alternately switched between traveling above and traveling below the glass disk 46 by means of a galvano-scan mirror 57 disposed at the same height as the glass disk 46. The resulting laser beams 60 and 61 are irradiated alternately onto the inner peripheral edge surface 47 of the glass disk 46 via mirrors 58 and 59 respectively. The connecting portion 42 has suitable openings 62 provided therein such that the laser beam 61 is not obstructed. The positions of the openings 62 can be calculated and set in accordance with the relationship between the speed of operation of the galvano-scan mirror 57 and the speed of rotation of the worktable 41.

[0073]

In the laser beam irradiation apparatus constructed as above, a semicircular plate-shaped mirror rotated by a motor or a stationary half mirror may be used instead of the galvano-scan mirror 57, as with the laser beam irradiation apparatus of FIG. 2. Moreover, it goes without saying that the setting of the ratio of the energy density of the laser beam 53 to the energy density of the laser beams 62 and 61, the possibility of making the mirrors 54, 57 and 58 convex, and so on are as was described in the case of the laser beam irradiation apparatus of FIG. 2.

[0074]

In the embodiments described above, the inner and outer peripheral edge surfaces of the glass disks 14 and 46 were both irradiated with a laser beam, but only one of the inner and outer peripheral edge surfaces may be irradiated with a laser beam.

[0075]

Moreover, in the embodiments described above, the size of the glass disks 14 and 46 was an outside diameter of 84mm, an inside diameter of 25mm, and a thickness of 1.0mm. However, it goes without saying that the outside diameter, the inside diameter and the thickness may take any values.

[0076]

According to the manufacturing process of FIG. 1, roughness in an amount corresponding to the diamond grindstones remains on the inner and outer peripheral edge surfaces of the glass disks 14 and 46 before the laser beam irradiation as shown in FIG. 6A, but the inner and outer peripheral edge surfaces after the laser beam irradiation of are smooth and edge portions adjoining the major surfaces are rounded as shown in FIG. 6B. That is, the polishing step of the conventional method (P4 and P5) can be omitted, and moreover the chamfering can be omitted in the grinding step (P3).

[0077]

According to the present invention, the smoothing of the inner and outer peripheral edge surfaces is a smoothing process step carried out by melting or making fluid the glass disk through laser beam irradiation. It is thought that melting and flowing of the glass in recessed parts of the inner and outer peripheral edge surfaces also occurs at the same time. The projecting parts of the inner and outer peripheral edge surfaces thus flow into the recessed parts, and hence the surface

is smoothed rapidly. Moreover, the smoothing is carried out in a dry state with only a laser beam coming into contact with the glass disk and without abrasive grains or fine metal oxide particles such as cerium oxide particles being used, and hence the glass is not soiled and foreign matter does not become attached to the glass. Furthermore, by focusing the laser beam energy onto the inner and outer peripheral edge surfaces of the glass disk, the smoothing can be carried out in a short time.

[0078]

In contrast, in the conventional smoothing process step carried out on the inner and outer peripheral edge surfaces is a combination of chamfering and polishing. Thus, projecting parts are ground down progressively from the top, and hence the polishing must be carried out until the ground surface reaches the bottom of the recessed parts. To do this while insuring adequate industrial productivity, coarse abrasive grains which give a high grinding rate may be used, but then there is a limit to how smooth the surface can be made. To achieve a good balance between the grinding rate and the degree of smoothing, usually a plurality of stages of grinding are carried out, each with a different size of abrasive grains, but this results in problems such as the equipment cost being high due to a plurality of pieces of equipment being required and the processing taking a long time. A characteristic of the smoothing according to the present invention is that these drawbacks suffered by the conventional art are not present.

[0079]

A description will now be given of examples of the present invention.

[0080]

In these examples, the undermentioned experiments were carried out with regard to the samples shown in

[0081]
[Table 2]

		Type of glass	Glass disk edge surface smoothing steps				Roughness of inner and outer peripheral edge surfaces			
			Wet processing steps carried out			Dry processing steps carried out	Average roughness Ra (μm)	Maximum roughness Rmax (μm)	Δ Ra	Δ Rmax
			First stage grinding using #324 roughness diamond abrasive grains	Second stage grinding using #500 roughness diamond abrasive grains	Precision polishing using suspension of cerium oxide fine powder	Smoothing by laser beam irradiation				
Example	1	Aluminosilicate glass	Yes	Yes	Yes	Yes	0.03～0.06	0.2～0.5	0.03	0.3
	2	Aluminosilicate glass	Yes	Yes	–	Yes	0.03～0.07	0.2～0.5	0.04	0.3
	3	Aluminosilicate glass	Yes	–	–	Yes	0.06～0.10	0.4～0.7	0.04	0.3
	4	Crystallized glass	Yes	Yes	–	Yes	0.03～0.04	0.2～0.3	0.01	0.1
Comparative example	1	Aluminosilicate glass	Yes	Yes	–	–	0.6～1.3	2.5～5.0	0.7	2.5
	2	Aluminosilicate glass	Yes	Yes	Yes	–	0.05～0.4	0.3～2.5	0.35	2.2

[0082]

(Example 1)

Samples of a glass substrate for a magnetic recording medium of outside diameter 84mm, inside diameter 25mm and thickness 0.8mm were prepared through step 1 to step 8 in that order as described below.

[0083]

Step 1) Preparation of starting material glass plate

A starting material glass plate was prepared by forming an aluminosilicate glass having 63.3mass% of SiO_2, 16.3mass% of Al_2O_3, 0.4mass% of K_2O, 1.9mass% of MgO, 3.8mass% of CaO, 3.7mass% of Li_2O_3 and 10.6mass% of Na_2O as principal components into a plate shape using a float glass manufacturing method.

[0084]

Step 2) Cutting out of glass disks

500 glass disks were produced by inserting cutting lines into a surface of the starting material glass plate at a position slightly outside the above-mentioned outside diameter and a position slightly inside the above-mentioned inside diameter using a diamond cutter, and cutting out along the cutting lines by applying an external force.

[0085]

Step 3) Grinding and polishing of inner and outer peripheral edge surfaces

Step 3A) First stage grinding of inner and outer peripheral edge surfaces

Each glass disk was fixed in a fixing jig, rotating grindgrains having #324 roughness diamond abrasive grains attached thereto were pushed against the edge surfaces of the glass disk, and grinding was carried out until the inside diameter and the outside diameter became the predetermined values.

[0086]

Step 3B) Second stage grinding of inner and outer peripheral edge surfaces

Each glass disk was fixed in a fixing jig, rotating grindstones having #500 roughness diamond abrasive grains attached thereto were pushed against the edge surfaces of the glass disk, and the roughness of the edge surfaces was reduced. Afterwards, the glass disk was washed with water.

[0087]

Step 3C) Precision polishing of inner and outer peripheral edge surfaces

100 of the glass disks for which the inner peripheral edge surface and the outer peripheral edge surface had been ground as above were stacked on top of one another and fixed, and, as shown in FIG. 7, precision polishing of the inner and outer peripheral edge surfaces was carried out by pushing cylindrical rotating brushes 4 and 5 made of a resin against the inner peripheral edge surfaces 2 and the outer peripheral edge surfaces 3 of the stacked glass disks 1 and feeding in a suspension containing cerium oxide fine powder from supply pipes 6 and 7. Afterwards, the glass disks were again washed with water.

[0088]

Step 4) Laser beam irradiation of inner and outer peripheral edge surfaces.

Next, the glass disks for which the inner edge surface and the outer edge surface had been precision polished were taken one at a time, and were smoothed by laser beam irradiation. The laser beam irradiation apparatus shown in FIG. 2 was used, and the smoothing processing conditions were as follows:

(1) Laser oscillator: Carbon dioxide laser (maximum rating 40W)

(2) Diameter of irradiated laser beam: Circle of diameter 3mm

(3) Laser power density: $4W/mm^2$

(4) Laser beam irradiation method: Scan once across each part of edge surface (adjust to divergent beam using lens)

(5) Speed of rotation of glass disk at outer periphery: 0.5m/minute

(6) Heating of glass: Central part in radial direction heated to about 200°C using nichrome electrical heater

Step 5) Grinding and polishing of major surfaces (information recording surfaces)

Glass disks which had been subjected to the laser beam irradiation were set into a resin carrier having a plurality of holes each having an inside diameter slightly larger than the outside diameter of the glass disks, an upper plate and a lower plate each having #500 roughness diamond abrasive grains attached thereto were pushed against the top and bottom respectively of the glass disks, thus sandwiching the glass disks in-between, and the plates were rotated, thus carrying out wet grinding of the major surfaces of the glass disks. Furthermore, as the later polishing step, precision polishing of the major surfaces of the glass disks was carried out by using a polishing machine having plates with resin pads attached thereto instead of the diamond abrasive grains, and feeding in #1000 roughness cerium oxide fine powder onto the major surfaces of the glass disks.

[0089]

Step 6) Washing

The glass disks were next washed with water to remove polishing abrasive grains and the like.

[0090]

Step 7) Chemical strengthening treatment

Chemical strengthening treatment was then carried out by immersing the glass disks for 3 hours in a molten salt of potassium nitrate heated to 450°C, thus replacing lithium ions and sodium ions near the surface layer the glass disk with potassium ions, and hence forming a compressed layer.

[0091]

Step 8) Washing

Finally, the glass disks soiled with the molten salt were washed with water.

[0092]

As described above, samples of Example 1 of glass substrates for magnetic recording medium were obtained. The roughnesses of the inner and outer peripheral edge surfaces of the 500 samples were recorded onto a chart using a stylus type roughness meter, and the average roughness Ra and the maximum roughness Rmax were calculated in accordance with a JIS-stipulated method. The results are shown in the "Example 1" row in Table 2.

[0093]

The average roughness Ra was low at 0.03 to 0.06μm, and moreover the range over which the Ra value varies was also small. The average roughness Ra obtained thus did not exceed 0.1μm, which is the value required for the glass disk to be suitable for use as a magnetic recording medium for high-density recording using a magneto-resistive head (an MR head or a GMR head). Furthermore, the maximum roughness Rmax was 0.2 to 0.5μm, and hence the maximum value of Rmax did not exceed 1μm, which is the value required for use in high-density recording.

[0094]

A glass substrate for a magnetic recording medium is manufactured through a plurality of processing steps, and usually washing with water, alkaline water, acidic water,

washing water or the like is carried out after each step. However, even by washing it is not easy to completely remove foreign matter (glass waste that arises through grinding and polishing, residual abrasive grains, dust from the air, metal powder worn off from machinery, etc.) attached to the edge surfaces of the glass substrate, especially in recessed parts. When the glass substrate is used as an information recording medium in a hard disk drive and rotated at high speed, there is a high probability of such attached matter flying off the surface of the information recording medium due to centrifugal force and attaching to the information recording surface. This results in an increased risk of magnetic head crashes.

[0095]

To reduce this risk, in general the washing is carried out thoroughly, and also roughness consisting of projecting and recessed parts on the edge surfaces of the glass substrate is reduced so that washing will be easier and foreign matter will be less likely to become attached. As shown in Table 2, in the case Example 1, all disks prepared had an average roughness Ra is 0.06μm or less and a maximum roughness Rmax is 0.5μm or less, showing that the edge surfaces have been processed well.

[0096]

Example 2

500 samples of glass substrates for information recording media were prepared using the same method as in Example 1, but the precision polishing of step 3C described above was not carried out. As shown in Table 2, the ranges of the average roughness Ra and the maximum roughness Rmax were about the same as for the samples prepared using the method of Example 1.

[0097]

Example 3

500 samples of glass substrates for information recording media were prepared using the same method as in Example 1, but only the second stage grinding of step 3B and the precision polishing of step 3C described above were not carried out. As shown in Table 2, the ranges of the average roughness Ra and the maximum roughness Rmax for the samples prepared using the method of Example 3 were shifted to slightly higher values compared with these ranges for the samples of Example 1, but were still satisfactory.

[0098]

Example 4

500 samples of glass substrates for information recording media were prepared as in Example 2, but a crystallized glass (75mass% SiO_2, 3mass% Al_2O_3, 4mass% K_2O, 12mass% Li_2O, 2mass% MgO, 3mass% P_2O_5, 1mass% ZnO) was used instead of the amorphous aluminosilicate glass as used in Example 1. The ranges of the average roughness and the maximum roughness for the samples of Example 4 were about the same as for the samples of Example 2.

[0099]

Comparative Example 1

500 Comparative Example samples 1 of glass substrates for information recording media were prepared without carrying out the smoothing process by laser beam irradiation. Comparative example samples 1 were prepared as the same in Example 1, but the precision polishing of step 3C and the laser beam irradiation of step 4 were not carried out. The range of the average roughness of the obtained samples was 0.6 to 1.3μm, showing that the edge surfaces obtained had a roughness about 10 times greater than in the other Examples. Moreover, regarding the maximum roughness Rmax, some samples had a low value of Rmax of 2.5μm, but there were also samples for which Rmax was high at 5μm. The presence of samples for which Rmax

is high means that there is a high possibility of there being glass substrates for information recording media within a production lot for which the possibility of attachment of foreign matter as described above is high, and hence a fear arises that it may not be possible to produce information recording media with high reliability.

Comparative Example 2

[0100]

With an aim of making the average roughness Ra and the maximum roughness Rmax lower than the samples prepared in Comparative Example 1, Comparative Example Samples 2 were prepared using the same method as in Comparative Example 1, but the precision polishing of step 3C was added to the wet processing steps; this precision polishing was carried out after the first stage grinding of step 3A and the second stage grinding of step 3B. As shown in Table 2, the average roughness Ra of the obtained 500 was lower than for Comparative Example 1. However, even though some samples had a low value of Ra of 0.05μm, there were some samples with a value of Ra of 0.4μm, and hence the value of the average roughness Ra varied over a broad range covering a factor of about 10. Moreover, regarding the maximum roughness Rmax, there were some samples having a high value of 2.5μm.

[0101]

From the above, it can be seen that in the case of the samples prepared using the methods of Examples, the average roughness Ra and the maximum roughness Rmax are distributed over a narrow range, but in the case of the samples prepared using the methods of Comparative Examples, the average roughness Ra and the maximum roughness Rmax are distributed over a broad range.

[0102]

According to Example 3 of the present invention, the wet processing carried out prior to the laser beam

irradiation comprises only a first stage grinding to adjust the inside and outside diameters to predetermined values and is possible to obtain low values and narrow distributions of the average roughness Ra and the maximum roughness Rmax. It can thus be seen that it is possible to reduce the number of processing steps.

[0103]

FIG. 8 is a graph showing the frequency distribution of the average roughness Ra over 500 samples of Example 2 and Comparative Example 2. The average roughness Ra has a narrow distribution in the case of the samples of Example 2, but a distribution about 8 times as broad in the case of the samples of Comparative Example 2. If hard disk drives were manufactured using glass substrates for magnetic recording medium having a roughness distribution such as that of the samples of Comparative Example 2, then because the roughness is high, one would anticipate that the probability of the problems described earlier occurring would be increased.

[0104]

[Effects of the Invention]

As described above, according to the method of manufacturing described in claim 1, at least one of the outer peripheral edge surface and the inner peripheral edge surface of a donut-shaped glass disk for information recording media is smoothed by melt-heating to a temperature at or above a softening point of the glass by irradiating with a laser beam. Therefore, at least one of the outer peripheral edge surface and the inner peripheral edge surface of the glass disk becomes smooth and rounded, and hence a polishing step used in a conventional method can be omitted, and moreover chamfering in a grinding step can also be omitted.

[0105]

According to the method of manufacturing described

in claim 5, both the outer peripheral edge surface and the inner peripheral edge surface are melt-heated in the smoothing step. As a result, the working efficiency can be improved.

[0106]

According to the method of manufacturing described in claim 9, the laser beam is a divergent beam. As a result, the laser beam can be reliably prevented from being irradiated the major surface of the glass disk and and thus melting the major surface of the glass disk.

[0107]

According to the method of manufacturing described in claim 11, the ratio of the energy density of the laser beam on the outer peripheral edge surface to the energy density of the laser beam on the inner peripheral edge surface is larger than 1. As a result, the difference in the energy density per unit area between the inner peripheral edge surface and the outer peripheral edge surface can be made small, and thus the difference in the degree of smoothness can also be made small.

[0108]

According to the method of manufacturing described in claim 12, the ratio of the energy density of the laser beam on the outer peripheral edge surface to the energy density of the laser beam on said inner peripheral edge surface is in a range of 2 to 5. As a result, the energy density per unit area can be made approximately the same for the inner peripheral edge surface and the outer peripheral edge surface.

According to the method of manufacturing described in claim 15, the mother glass of the glass disk is a silicate glass containing at least Li_2O or Na_2O as an alkaline oxide component, and the method further comprises the step of carrying out chemical strengthening treatment wherein an alkaline component in a surface

layer of the glass disk is replaced with an alkaline component having a larger ionic radius, after the smoothing step has been carried out on the major surface of the glass disk.

[0109]

According to the glass substrate for information recording media described in claim 16, the glass substrate is prepared using the method as claimed in any one of claims 1 to 15. As a result, a glass substrate wherein at least one of the inner peripheral edge surface and the outer peripheral edge surface is smooth can be obtained.

[0110]

According to the glass substrate for information recording media described in claim 19, the glass substrate for information recording media as claimed in any one of claims 16 to 18 is formed with an information recording film on the major surface thereof. As a result, an information recording medium wherein foreign matter does not attach to the major surface(s) thereof can be obtained.

[0111]

Also, according to the present invention, an information recording medium can be obtained by forming an information recording film such as a magnetic recording film, an optical magnetic recording film or an optical recording film on one or both major surfaces of the glass substrate for information recording media according to the present invention as described above.

[0112]

The information recording medium of claim 20, is an information recording medium as claimed in claim 19, wherein the information recording film is a magnetic recording film.

[Brief Description of the Drawings]

[Fig. 1]

FIG. 1 is a flow chart of a manufacturing process for a glass substrate for information recording media according to an embodiment of the present invention.

[Fig. 2]

FIG. 2 is a partially sectional view of an example of a laser beam irradiation apparatus used in step P14 shown in FIG. 1.

[Fig. 3]

FIG. 3 is a perspective view of a semicircular plate-shaped rotating mirror in the laser beam irradiation apparatus shown in FIG. 2.

[Fig. 4]

FIG. 4 is a view useful in explaining a mirror in the laser beam irradiation apparatus shown in FIG. 2.

[Fig. 5]

FIG. 5 is a partially sectional view of a modified example of the laser beam irradiation apparatus used in step P14 shown in FIG. 1.

[Fig. 6]

FIG. 6 are views useful in explaining the roughness of a peripheral edge surface of a glass disk; specifically, (a) shows the peripheral edge surface after grinding in the grinding process, and (b) shows the peripheral edge surface after the laser beam irradiation.

[Fig. 7]

FIG. 7 is a schematic view useful in explaining a precision polishing apparatus for polishing the inner and outer peripheral edge surfaces of stacked glass disks, as used in step 3C in Example 1.

[Fig. 8]

FIG. 8 is a graph showing the frequency distribution over 500 samples of the average roughness Ra obtained in Example 2 and Comparative Example 2; and

[Fig. 9]

FIG. 9 is a flow chart of a conventional manufacturing process for a glass disk for a magnetic disk.

[Description of Reference Numerals]

11,41	worktable
14,46	glass disk
20,50,51	laser oscillator
21,52,55	collimator
23,57	galvano-scan mirror
26,27,28,58,57	mirror